LA-UR-77-2247

Conf-771031--3

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SUBMITTED TO: 21st Conference on Analytical Chemistry in Energy Technology, Gatlinburg, Tennessee, October 4-6, 1977

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Form No. 836
St. No. 2629
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UNITED STATES
ENERGY RESEARCH AND
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CONTRACT W-7405-ENG. 36

NONDESTRUCTIVE ASSAY INSTRUMENTS FOR THE DYMAC PROGRAM AT THE LOS ALAMOS SCIENTIFIC LABORATORY*

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ABSTRACT

A real-time, nuclear materials control system, called DYMAC, will begin operation in November at the new plutonium processing facility at the Los Alamos Scientific Laboratory. The DYMAC system relies on three types of nondestructive assay instruments to control nuclear material dynamically: weighing instruments, neutron counters, and gamma counters. Remoted electronic balances and load cells weigh the nuclear material in process. DYMAC uses two types of neutron counters, thermal-neutron coincidence counters and fast-neutron coincidence counters. There are two types of gamma counters, one assays liquids and another solids; both are gamma spectroscopy instruments which use germanium detectors.

A major criticism leveled against nuclear generation of electrical power is that facilities have inadequate control over their nuclear material. Headlines over the past few years have proclaimed the "loss" of large quantities of weapons-grade nuclear materials at both private and government nuclear facilities. Those of us who work closely with nuclear accountability groups realize that these "losses" are attributable to equipment hold-up, accountability errors, or biased analyses of scrap materials.

*Work performed under the auspices of the US Energy Research and Development Administration.

Late in 1975, the Nuclear Safeguards group at LASL received ERDA funding to design and build a nuclear materials control system. The system is being installed at a new replacement facility for the old plutonium processing buildings that have been in use since 1943. We have named the system DYMAC, for DYnamic MAterials Control. DYMAC integrates nondestructive measurement instrumentation and interactive terminals with a central computer. DYMAC must provide an accurate, real-time nuclear materials control system by mid-1978 when the new facility is scheduled to begin processing plutonium.

I shall focus my discussion on one aspect of the DYMAC system: the NDA instruments which are presently being installed in the new facility.

In terms of quantity, the most popular instrument is the electronic balance. We are installing thirty-two 5.5-kg balances and three 15-kg balances. All of the balances read to the nearest 0.1 g except five 5.5-kg balances which read to 0.01 g. Figure 1 shows a 5.5-kg Arbor balance. Notice that it is remoted: the weighing and readout units are separate. For glovebox installations, the relatively rugged weighing unit will be positioned inside the glovebox and the readout unit outside. Signals are transmitted through the glovebox via hermetically sealed bulkhead penetrations. Bench testing has shown that even with 25 ft of remoting cable, the balances still meet specifications; specifically, the 0.1-g sensitivity balances demonstrate a 1σ precision of ± 0.1 g. We expect a slight deterioration in performance in glovebox applications primarily because of noise pickup through the remoting cable. The

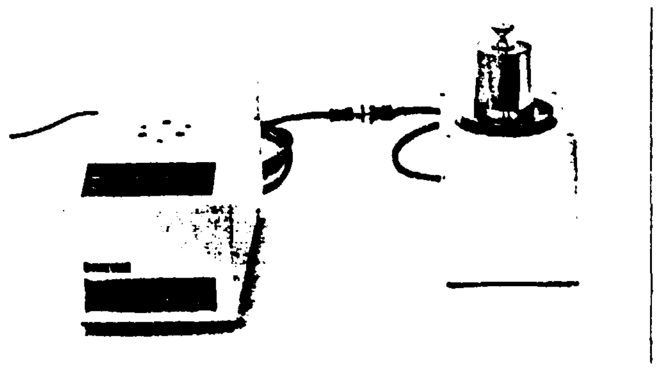


Figure 1. Remoted electronic balance.

balances will be used to weigh relatively pure nuclear material such as PuO_2, plutonium metal, UO_2, or impure nuclear material of known content such as uranium-plutonium oxides and carbides or impure PuO_2 which has been previously assayed.

A second type of weighing device is the load cell. These devices will be used to weigh tanks of solutions generated in the scrap recovery area. The 60-L tanks are located in gloveboxes and suspended by load cells as shown in Figure 2. Notice the load cell is located outside the glovebox and connected to the tank via cables and a steel rod-and-bellows arrangement which seals the glovebox yet permits freedom of movement. We would have preferred to suspend the tank by a single cable and load cell mounted along the tank centerline, but the stirring motor and shaft interfered. By paying careful attention to the vertical alignment of the tank, we can weigh 30-60 L in the tank to better than a 1σ precision and accuracy of 1%.

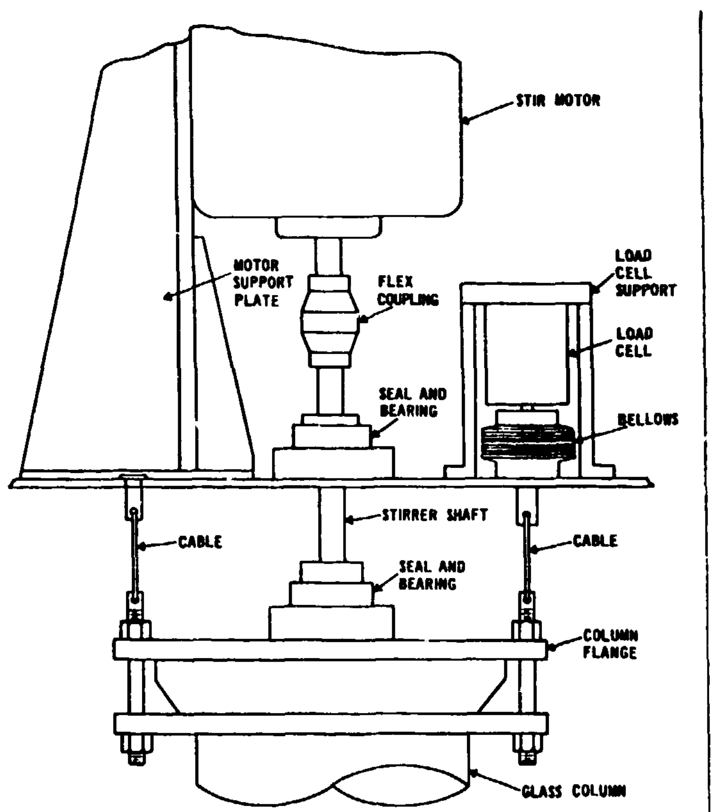


Figure 2. Load-cell tank suspension.

The instrument we will use to measure plutonium concentration in solutions is the solution assay instrument. It counts the 414- and 128-keV gamma-ray peaks from ^{239}Pu and calculates plutonium concentration from peak areas. Figure 3 is a cutaway of the sample holder and the germanium detector. Solution samples are dispensed into special polystyrene bottles, weighed, and then placed into a recess in the sample holder. The sample holder is heavily shielded with lead to minimize background. Gamma rays emitting from the sample pass through the floor of the glovebox and into an intrinsic germanium detector (not a Ge-Li detector, as shown). No thinning of the glovebox floor is required because the 3/16-in. stainless steel floor transmits an adequate fraction of the gamma-ray signal.

Heavy lead shielding isolates the detector from background gamma rays. We correct for gamma-ray attenuation in the sample by rotating a 20-g plutonium source into the plane of the sample and measuring the attenuated count rate. The gamma-ray signal is sent to a multichannel analyzer. Corrections are made for attenuation, background, and deadtime. Figure 4 shows the germanium detector positioned under a glovebox and a sample holder within the glovebox.

Glovebox evaluation of the instrument shows that we can expect accuracy and precision better than 1% for

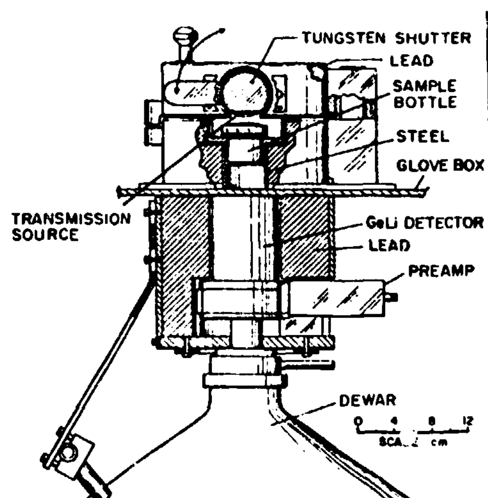


Figure 3. Cutaway of solution assay instrument.

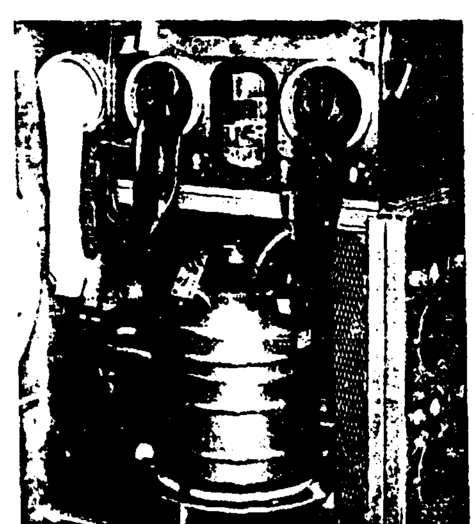


Figure 4. Glovebox installation of solution assay instrument.

solutions in the 5-100 g Pu/L range. Waste solutions as low as 0.05 g Pu/L can be assayed with reasonable accuracy.

By multiplying the bulk solution weight as measured by load cells times the sample concentration determined with the solution assay instrument and electronic balances, we obtain a measure of the plutonium content in the bulk solution. By eliminating bagging out and transporting samples, analysis time is reduced from several days to one hour.

An instrument we will rely on for assaying various plutonium-bearing solids is the thermal-neutron coincidence counter. It distinguishes fission neutrons generated in pairs, or coincidence, from background single neutrons generated by (α,n) reactions. The thermal-neutron counters will be used to measure 0.5 g to kilogram quantities of plutonium in a wide range of matrices.

Figure 5 shows a thermal-neutron counter being assembled on top of a glovebox. The 6-in.-diameter counting chamber and polyethylene shielding framework are visible. Figure 6 shows some of the polyethylene shielding in place and the ring of ^{3}He detector tubes being lowered around the counting diameter.

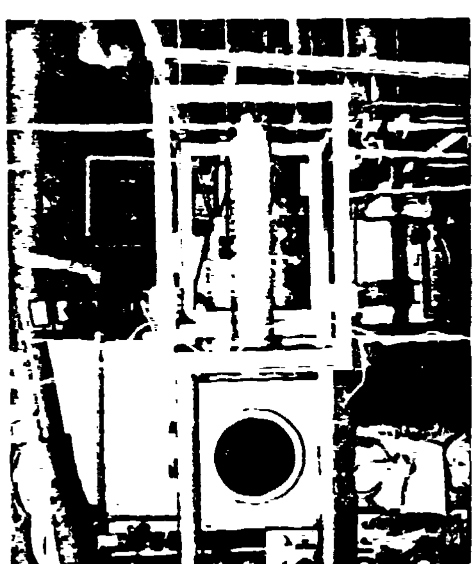


Figure 5. Thermal-neutron coincidence counting chamber mounted on top of glovebox.

Figure 6. Polyethylene shielding and ^{3}He detector tubes being assembled.

The 15 thermal-neutron counters being installed at the new facility will measure plutonium metal, PuO_2, uranium-plutonium carbide, miscellaneous scrap, and possibly even bottles of high-concentration plutonium nitrate. We anticipate difficulties in assaying kilogram quantities of plutonium metal and a few categories of scrap but expect 5% accuracy when measuring PuO_2, uranium-plutonium carbide, and most categories of scrap.

Materials with very high singles neutron backgrounds cannot be assayed via thermal-neutron coincidence counting. We are building a special counter for such materials: a fast-neutron counter. It uses plastic scintillators to detect unmoderated (fast) neutrons and only counts neutron pairs coincident in the time interval 5 to 40 nanoseconds. The instrument can be operated either passively, counting spontaneous fission neutrons, or actively, counting induced fission neutrons. Although the fast-neutron counter is limited to a minimum sample size of about 50 g of plutonium, it appears to be much more accurate than the thermal-neutron counters for PuF_3, PuF_4, and kilogram quantities of plutonium metal.

Figure 7 shows the segmented gamma scanner. Although it is not built into the glovebox line, it is

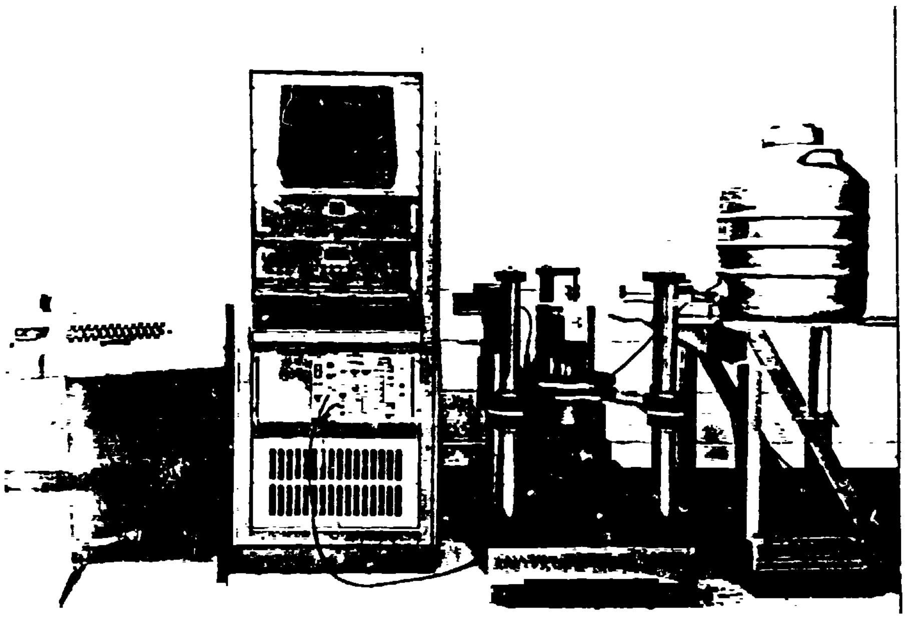


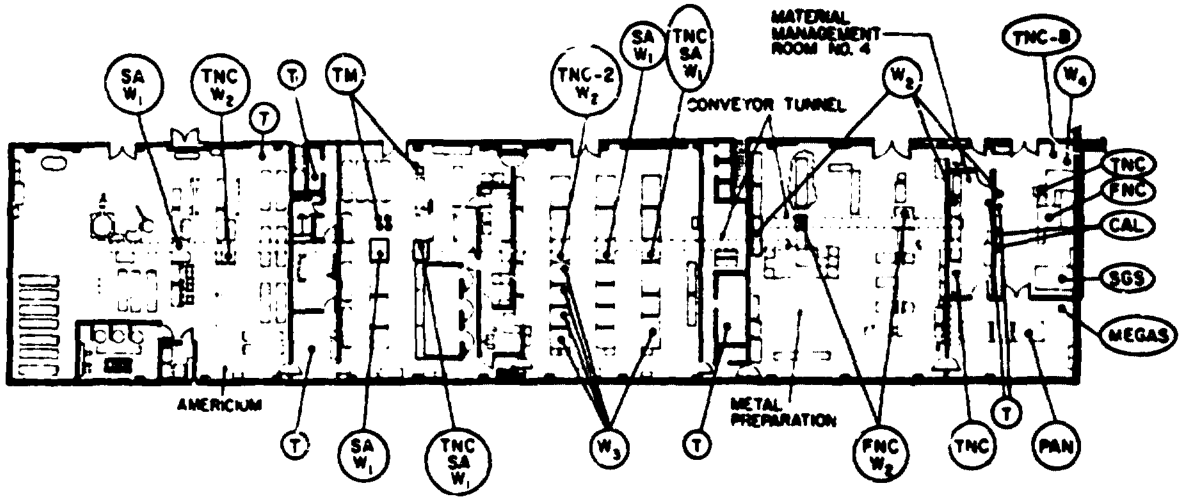
Figure 7. Segmented gamma scanner.

widely used to assay packaged cans of plutonium scrap such as incinerator ash. Cans of nuclear material are rotated and raised in a series of 1-cm steps into the counting window of the Ge-Li detector; when it is in place the ^{239}Pu gamma peaks are counted. Next, a shutter opens on a ^{75}Se source and the 401-keV gamma rays passing through the segment are counted. Each segment count rate is corrected for transmission losses and the plutonium content of each segment is calculated. The segments are summed to give the total plutonium content of the can.

Figure 8 shows the DYMAC instruments located in the scrap recovery wing of the new facility. We have located neutron coincidence counters throughout the wing. The room on the extreme right of Figure 8 has a thermal-neutron coincidence barrel counter (NC_1) for assaying 30-gal drums of waste containing small quantities of plutonium. The room also has a fast-neutron and a thermal-neutron coincidence counter for assaying small cans of nuclear material. Two calorimeters and a segmented gamma scanner are also planned for this room. Installation of the calorimeters has been postponed due to lack of funding.

The two instruments labeled M and P measure very low-level waste destined for burial; they will not interface with the DYMAC system. Two fast-neutron counters are located in the metal preparation room where PuF_3, PuF_4, and large quantities of plutonium metal are generated. Five additional thermal-neutron coincidence counters are located throughout the other main rooms in this wing. Five solution assay (SA) instruments are located in rooms where solutions are generated or processed. The tank assay system (TA) has been ruled out as impractical. However, solutions to be stored in tanks outside the glovebox system will be assayed prior to transfer. Balance locations (W_1 and W_2) indicated in Figure 8 are correct but the ranges have changed: W_1 units have a 0-5 kg range and W_2, 0-15 kg. Interactive terminals (T_1 and T_2) allow personnel to communicate with the central computer; they are located in major work areas and some offices. The T_2 is a supervisory terminal with hardcopy printout.

The DYMAC program depends on the accurate and timely measurements provided by this assemblage of gamma counters, neutron counters, and weighing instruments in the new facility to achieve its goal: to provide real-time control of nuclear material.



FNC	Fast-neutron coincidence counter	TNC	Thermal-neutron coincidence counter
MEGAS	Multienergy gamma scanner	TNC-2	TNC, low range (1-50 g of plutonium)
PAN	Pancake counter	TNC-B	TNC for barrels
SA	Solution assay instrument	W_1	Electronic balance, 0-200-2,000 g
SGS	Segmented gamma scanner	W_2	Electronic balance, 0-10,000 g
T	Interactive terminal, floor model	W_3	Load cells
T_1	Interactive terminal, supervisory model	TM	Tank measurement, gamma or x ray

Figure 8. DYMAC instruments in the recycle area.